

DRAFT REPORT

**A COOPERATIVE PLAN TO ADMINISTER THE
YELLOWSTONE RIVER COMPACT**

by

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I. INTRODUCTION

(A) Analysis of the Compact

On October 30, 1951, the Yellowstone River Compact was approved by the states of Wyoming, Montana, and North Dakota. The intent of the Compact is to establish the process for apportioning water in the four tributaries of the Yellowstone River. Analysis of the Compact would lead one to believe that drafters of this document intended that flow during periods of high runoff would someday be stored and then apportioned on a percentage basis for later use. Therefore, the real purpose of the Compact is to divide excess spring flow.

The Yellowstone River Compact recognizes all water rights existing as of January 1, 1950. The result is that the Compact does not address the division of water during extremely low flow periods because the majority of appropriations in the Yellowstone Basin have a priority date earlier than 1950. If there is insufficient water to satisfy all pre-1950 uses in both states, Wyoming water users would first satisfy their pre-1950 demands. Montana users could then appropriate the remainder, including the accumulated return flow generated in Wyoming. Because agricultural and industrial development since 1950 has been minimal, the need to regulate post-1950 appropriations in Wyoming for the purpose of satisfying pre-1950 appropriations in Montana would also be minimal.

Along with providing for water allocation, the Yellowstone Compact constitutes an important deterrent to the out-of-basin transfer of water. Article X of the Compact states that no water may be transferred out of the basin without consent of all three signatory states. The intent of this Article is to protect existing appropriators in both states who depend almost entirely upon the reuse of return flow. The issue of reusing return flows is important to both states because Article V apportions flow based on diversions, not on depletions. Therefore, if return flows are not available for reuse, downstream appropriators could be harmed. As an example, a pre-1950 agricultural diversion right to 500 acre-feet which is changed to an industrial use and exported out of the basin could potentially impact an additional 375 acre-feet of downstream agricultural diversions. Article X protects these downstream users.

Section C(4) of Article V of the Compact suggests that water which flows past the point of measurement provided by the Compact and leaves the system "from October 1 to any given date" is allocable flow. The analysis of the historic flow at this point of measurement would be useful in calculating the historic apportionment, for sizing new reservoirs, or for analyzing potential development in the basin. However, in terms of real-time administration of the Yellowstone Compact, the division of water as it leaves the system does not make sense because it is physically unavailable for upstream use. For

example, if 150,000 acre-feet pass the point of measurement from October through April, it would be defined as "allocable flow" by Article V. While this flow is "allocable" in a historic sense, it certainly is no longer available for use during the May through September irrigation season. Therefore, for purposes of real-time compact administration, this 150,000 acre-feet should probably shift from an "allocable" account to an "unused and presently unavailable" account.

(B) Need for Compact Administration

Since 1951, the consensus of the Yellowstone River Compact Commission has been that the level of water resources development in the basin has not warranted administration of the Compact. Recently, however, the demand for Compact administration and irrigation water management in the Yellowstone Basin has been growing. There are a number of reasons for this. First, Wyoming and Montana would like to develop their share of unused and unappropriated post-1950 Compact water. In Montana, a number of storage projects have been planned and the state is proceeding with steps to place reserved water to use. Both Montana and Wyoming either have or are looking to establish in-stream flow requirements for fish and wildlife. In addition, the State of Montana has taken the position that the development of water in the Missouri River Basin should be an integral part of any strategy whose purpose is to protect the water development interests of Upper Basin states from downstream demands.

Second, there is the potential for appropriating large quantities of water for industrial purposes and for water marketing. As an example, the Yellowstone River Pipeline Company recently filed an application for a permit to appropriate 345 cubic feet per second from the Yellowstone River mainstem. This flow would be considered part of Wyoming's entitlement under the Yellowstone Compact. If Montana granted this permit, or if water was sold from storage for industrial purposes, a mechanism to administer the Yellowstone River Compact should be in place.

Third, reports published by the State of Wyoming have discussed exchanges of Compact water between tributaries in the Yellowstone Basin. In order for an exchange to take place, an administrative process would be needed that could quantify and account for the exchange.

(C) Scope of this Report

The objective of this report is to provide the State of Montana with a plan to administer the Yellowstone River Compact. Administration of the Compact will most likely prove to be a costly and time consuming endeavor. For this reason, the proposed plan prioritizes activities based on their financial and political feasibility, and then organizes them into five distinct project phases. It is assumed in this plan that all five project phases cannot be implemented

simultaneously, and that the rate of progress from one phase to the next will depend on the level of available funding and the perceived need for water resources management and Compact administration.

This management plan stresses the importance of measuring and keeping accurate records of water use. Without this data the Yellowstone River Compact cannot be administered. Therefore, the question of determining actual water use may be the single, most critical issue to be resolved by water managers in the Yellowstone River Basin today.

II. PURPOSE

The underlying goals of the proposed management plan are:

1. To identify and prioritize certain tasks that need to be accomplished in both Wyoming and Montana in order to administer the Yellowstone River Compact.
2. To suggest a preferred course of action and outline the strategy necessary to accomplish each task.
3. To analyze the preferred course of action for potential problems or areas of conflict.

Implementation of this plan should result in the following:

1. Develop documentation of actual diversions and water use. These records are essential for Compact administration and can also serve as evidence for intrastate or interstate water rights litigation.
2. Allow the quantification of allocable flow on a weekly interval, or at other intervals to be determined by the Compact Commission.

3. Provide assurance that the State of Montana and Wyoming would receive their share of allocable flow.
4. Enable the generation of forecasts for the actual flow expected at streamgages in the basin headwaters and at the state line. These forecasts would be necessary to determine inflow to the river system. A knowledge of inflow would be useful in helping water commissioners regulate reservoirs and headgates, and would be used as input for hydrologic modeling.
5. Promote efficient irrigation water management practices that would increase agricultural production and decrease soil erosion in Wyoming and Montana.

III. METHODOLOGY

(A) Description of the Plan

In order to accomplish the objectives listed in Section II, this plan suggests a five phase process which relates directly to the organization of water rights data, water-use measurement, and to the development of a computer program which can be used to predict divertable flow and also calculate the Compact apportionment. The five suggested phases are:

Phase I - Water Appropriations Data Organization

Phase II - Streamflow Forecast Development

Phase III - Determination of Irrigation Water Use

Phase IV - Intrastate Admeasurement and Interstate
Communication

Phase V - Compact Administration

Due to limitations in funding and political feasibility, each phase would be implemented in a step-wise manner. The short-term goal would be to lay as much groundwork as possible in the Yellowstone Basin before Compact administration is absolutely necessary. The advantage to this approach is that the requisite data base would be compiled, and the necessary equipment would be in place and calibrated when the decision to administer the Yellowstone Compact is made.

Before discussing each of these five phases in detail, the mathematical basis for administration of the Yellowstone Compact is introduced along with a number of simple algebraic equations based on the provisions of Article V. That article defines the quantity of water to be allocated to each state and is equal to a percentage of the sum of the following terms:

1. Total post-1950 diversions in each state.
2. The net change in storage in post-1950 reservoirs in each state.
3. The net change in storage in pre-1950 reservoirs existing prior to 1950 which is used for irrigation, municipal, or industrial purposes that developed after 1950.
4. The flow past the point of measurement specified by the Compact.

A detailed summary of Article V is presented in Appendix A.

(B) Mathematical Basis and Equations for Administration of the Yellowstone Compact

It is proposed that the Compact be administered on a weekly basis using the following algebraic equations to apportion water on each tributary:

Equation 1

$$Q (\text{accumWY}) = \sum_1^N D(\text{WY}) + \Delta S(\text{WYpost50}) + \Delta S(\text{WYpre50})$$

(This equation states that the accumulation of water used in Wyoming from "October 1 to any given date" subject to the percentage allocation is equal to the sum of the accumulated diversions from day 1 through the N-th accounting period, plus the net change in storage in Wyoming's post-1950 reservoirs, plus the net change in storage from Wyoming's pre-1950 reservoirs used for purposes developed after 1950.)

Equation 2

$$Q (\text{accumMT}) = \sum_1^N D(\text{MT}) + \Delta S(\text{MTpost50}) + \Delta S(\text{MTpre50})$$

(This equation is the same as Equation 1, except the calculation is for Montana.)

Equation 3

$$Q (\text{accum}) = Q (\text{accumWY}) + Q (\text{accumMT}) + \sum_1^N Q (\text{compact gage})$$

(This equation states that the total accumulated flow to which the percentage allocations should apply is equal to the

sum of the accumulated water use in Montana and Wyoming, plus the flow past the point of measurement specified by the Compact.)

Equation 4

$$Q (\text{allocWY}) = Q (\text{accum}) \times w$$

(This equation states that Wyoming's Compact entitlement equals the total volume of water to which the percentage allocation applies, times the specific percentage allocation for any particular tributary.)

Equation 5

$$Q (\text{allocMT}) = Q (\text{accum}) \times m$$

(Same as equation 4, except the calculation is for Montana.)

Where, the terms in these five equations are defined as follows:

- $Q (\text{accumWY})$ - The accumulation of Wyoming diversions and storage changes since October 1.
- $Q (\text{accumMT})$ - The accumulation of Montana diversions and storage changes since October 1.

- D(WY), D(MT) - Diversions for post-1950 uses in Wyoming and Montana, respectively.
- $\Delta S(WY_{post50})$ - Net change in storage in post-1950
 $\Delta S(MT_{post50})$ reservoirs in Wyoming and Montana, respectively.
- $\Delta S(WY_{pre50})$ - Net change in storage in pre-1950
 $\Delta S(MT_{pre50})$ reservoirs used for post-1950 water rights in Wyoming and Montana, respectively (storage changes used for pre-1950 rights are ignored).
- Q (compact gage) - The flow passing the point of measurement specified in the Compact.
- Q (accum) - The total water from October 1 to the calculation date to which the allocation percentages will be applied.
- Q (allocWY),
 Q (allocMT) - The calculated quantity of water allocated to Wyoming and Montana, respectively, since October 1.
- w, m - The percent of Q(accum) that Wyoming and Montana, respectively, are assigned by the Compact, such that $w + m = 100\%$

- The N-th accounting period where N cycles from 1 to the last accounting period.

The key to practical application of the equations presented in the above section would be in the regulation of headgates and the admeasurement of irrigation water. Regulation of $D(WY)$ and $D(MT)$ must force $Q(accumWY)$ in equation 1 to be less than or equal to $Q(allocWY)$ in equation 4, and also force $Q(accumMT)$ in equation 2 to be less than or equal to $Q(allocMT)$ in equation 5. At the same time $Q(compact\ gage)$ must be minimized, since any extra flow at this point would indicate that either $D(WY)$ or $D(MT)$ is too small.

"Trial and Error" Method

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1. Measure the inflow above diversions.
 2. Estimate the level of use that could be satisfied with this inflow [D(WY) and D(MT)].
 3. Regulate headgates to obtain this level of use.
 4. Measure water-use as well as any flow at the point of measurement specified by the Compact.
 5. Calculate Q(accum).
 6. Compare Q(accumWY) with Q(allocWY).
 7. Compare Q(accumMT) with Q(allocMT)
 8. IF: Q(allocWY) is greater than Q(accumWY)
THEN: Wyoming diversions could increase, if
the demand exists.

OR
IF: Q(allocWY) is less than Q(accumWY)
THEN: Wyoming diversions should decrease.
- NOTE: The same comparison would hold for Q(accumMT)
and Q(allocMT).

9. If needed, adjustments in accounting could be made during the following accounting period to correct for errors in regulating D(WY) and D(MT).
10. Repeat steps 1 through 9 at the beginning of each accounting period in order to maintain equilibrium.

The "Trial and Error" method could be significantly improved if the system was calibrated based on past experience and if the available water supply for the next accounting period could be forecasted. These two improvements form the basis of the "Forecast" method described in the next section.

"Forecast" Method

The "Forecast" method consists of the following steps:

1. Forecast inflow above diversions for the next accounting period. This includes the mainstem and any major tributaries in either state.
2. Compare this inflow with historic inflows.
3. Consult a river calibration curve to identify the historic divertable flow at this level of inflow.

NOTE: The calibration curve would plot the average rate of inflow above diversions for the accounting period on the Y-axis, and the "divertable flow" that could be allocated to each state on a specified percentage basis on the X-axis. An example calibration curve and the accompanying explanatory discussion are contained in Appendix B.

4. With the use of a computer model project the divertable flow and Compact apportionment for the next accounting period.
5. Continue with step 3 of the "Trial and Error" method. If the divertable flow forecast was sufficiently accurate, plot this new data point on the calibration curve.

The "Forecast" method is more desirable than the "Trial and Error" method because:

1. It provides a guide to water commissioners on how headgates could be set at the beginning of each Compact accounting period.

2. It minimizes error and the need for "adjustments" in allocable flow. In-field water rights administration should be less expensive because less time would be needed in regulating headgates.
3. Minimal error and fewer headgate adjustments would increase project credibility among those appropriators who are being regulated.
4. It provides a method to continually update the calibration through time. The curve becomes more accurate and fine-tuned as additional data points are added.
5. The calibration curve would be combined with a simple computer program which could administer the Article V apportionment on a real-time basis.

The remainder of the Methodology section presents a detailed description of each phase of this plan. For each phase, the principle objectives are listed along with a preferred course of action to accomplish these objections. The preferred course of action has been organized into a list of activities which have been prioritized, and analyzed for potential problems or conflicts.

Phase I - Water Appropriations Data Organization

Objectives

The objective of the first phase would be to distinguish the difference between water rights claims and actual water appropriations, and then organize the water appropriations according to location of headgate, priority date, and flow rate. Water appropriations need to be tabulated in this fashion in order to facilitate headgate regulation, and to determine the quantity of pre-1950, post-1950, and supplemental flow that can legally be diverted.

Preferred Course of Action - Phase I

Activity A

Field check all claims and permits for location of headgate and canals, priority date, and flow rate. Establish the ditch capacity at the headgate. The Department should then file objections on all speculative or abandoned claims affecting state projects. All other speculative or abandoned claims should be informally noted and filed for future reference.

Activity B

Overlay verified water rights data on a mosaic of aerial photographs and U.S.G.S. topographic maps in order to gain an understanding of the spatial distribution of diversions and expected return flows. This information would be necessary for the development of accurate computer models, and would also be a valuable reference for water commissioners and hydrographers.

Activity C

Organize verified water appropriations on a master "Ditch List" according to headgate location. Priority dates and flow rates for each ditch would also be punched onto a metal tag and permanently mounted near the headgate. Water commissioners would find these tags extremely useful in regulating headgates, and their presense would help decrease the frequency of disputes among water users.

Appendix C presents a comparison on how similar water rights in Wyoming and Montana would be organized. Exhibit 1 of Appendix C presents a sketch and short history of water use for "Rod's A-1 Canal". (A fictitious example based on fact.) Exhibit 2 compares Wyoming and Montana water rights filings on Rod's A-1 Canal. Exhibit 3 is an example of the respective ditch lists. Exhibit 4 presents an example of the tag that would be mounted on the headgate.

Potential Problems - Phase I

There are three areas of conflict that have been identified in accomplishing the activities listed in Phase I.

1. Water rights claims in Montana, and decreed rights outside of the Powder River Basin do not necessarily reflect actual water use. At the present time, one finds an inconsistency in the manner in which enlargements and supplemental irrigation are treated in individual claims. This inconsistency results in duplicate counting of irrigated acres and flow rates. Therefore, a computer program that simply totals the information found in these claims gives inflated results.
2. Because of the limitations which have been imposed on the Department by the Water Courts and the legislature, the present adjudication effort will only provide the State with a tabulation of historic claims. A change in legislative goals and directions, as well as additional funding would increase the robustness of the adjudication process in the following ways:
 - a) Water rights claims could be verified in the field. This would be more accurate than the present method of office verification via

aerial photographs, and would be necessary for a reliable adjudication.

- b) Cases involving, speculation, abandonment or incremental development could be sufficiently analyzed. The Department would then have complete and accurate data with which to file objections.
- c) The actual volumes and flow rates for each appropriation would be more accurate because they would be measured.
- d) Legal land descriptions could be assigned to each place of use.
- e) There could be an in-depth analysis of land ownership.

3. The State of Wyoming applies a legal standard to the amount of water that can be diverted to irrigate a certain number of acres. This standard is equal to 2 cfs per 70 acres for water rights with a priority earlier than 1945, and 1 cfs per 70 acres for water rights with a priority later than 1945.

Montana, on the other hand has no consistent legal standard and the present system of water rights adjudication uses a "capping standard" based on flow rate, climatic area, and crop consumptive uses to identify and reduce unjustifiably large claims.

The result is that a ditch company may own very different water rights depending on whether it is located in Wyoming or Montana. Although legal, this inconsistency and bias may become a politically sensitive issue when water rights are regulated on an interstate basis.

Conclusion - Phase I

Administration of the Yellowstone River Compact depends on the availability of accurate and up-to-date water appropriation information including actual irrigated acres, flow rates, and priority dates. At the present time, this information is not available, and subsequently, the basin's water resources are not truly managed. Water management requires an intensive adjudication such as the one in the Powder River Basin. Originally, it was assumed that the statewide adjudication would proceed according to the methodologies developed for the Powder River Basin. Recently, however, the Water Courts have interpreted the intent of the legislature to favor the expeditious adjudication of a "general water rights list" where

specific features are stated but are unverified or loosely verified. This list will probably be subject to future modification through judicial argument and possibly by administrative approval. The DNRC therefore has two options which it could pursue in order to fulfill the objectives of Phase I. These options include:

1. Clarify the intent of the legislature and redefine the goals and objectives of the statewide adjudication to more closely resemble the adjudication in the Powder River Basin. Obtain legislature support for these activities as well as an adequate level of funding.
2. Object vigorously to every decree.

Phase II is presented in the next section. This phase suggests that the State of Montana enter into a cooperative agreement with Wyoming and the Soil Conservation Service to purchase, install, and maintain stream gages and certain telemetry equipment in order to generate streamflow forecasts for each tributary in the Yellowstone Basin.

Phase II - Streamflow Forecast Development

Objectives

The objectives of Phase II include the purchase and installation of SNOTEL-related equipment and the development of computer software that could forecast streamflow based on snowmelt and other meteorological parameters. Forecasts of streamflow would be necessary for the following reasons:

1. In order to admeasure water, water commissioners and hydrographers would need to know the inflow above diversions at key points on any particular stream. A streamflow forecast for the compact accounting period would give the range of inflows expected during that time period. Based on this information, water commissioners could select ^{the proper} ~~an average~~ headgate setting for the accounting period and eliminate the need for daily adjustments.
2. Valid application of the computer model and calibration curve is predicated on an accurate forecast of inflow.
3. Streamflow forecasts would help facilitate basin wide water management because water users could schedule irrigation based on projected supply.

It is suggested that the U.S. Department of Agriculture, Soil Conservation Service (SCS) be responsible for the development of streamflow forecasts because that agency has considerable experience and expertise in the area of forecasting. Furthermore, the SCS is in a position to act as an independent third party, and could issue credible and unbiased forecasts on each tributary affected by the Compact.

Preferred Course of Action - Phase II

Activity A

Retrofit existing SNOTEL sites with micro-circuit boards that would integrate air temperature at 15-minute intervals. This data would be necessary in order to more accurately forecast snowmelt.

Activity B

Identify basins that do not have a streamflow gage located above major diversions in the basin headwaters. Formulate a cooperative arrangement between Wyoming, Montana, and the United States Geological Survey (USGS) to finance and install these new gages. Each gage would need telemetry capability because real-time data from these gages would be used for the calibration and operation of streamflow forecasts.

Activity C

Identify basins that do not have a sufficient number of weather stations. Finance and install these new weather stations. Climatological data would be most important in basins where streamflow is more dependent on local precipitation than on high mountain snowmelt (i.e.-Powder River Basin).

Activity D

Identify USGS stream gages which are located at the state line or at the compact measurement points that do not have telemetry capability and telemeterize such gages. Real-time flow data from a system of telemetered gages would be necessary to guide water commissioners, administer the compact, and verify that Montana's allocation actually crosses the state line.

Activity E

Compile historic snow-pillow, stream gage, and weather data for each basin. Enter this information into a computerized data base for use in the development of the snowmelt-streamflow forecasts.

Activity F

Develop the software and statistics to analyze the parameters listed in Activity E and construct a computer model for each basin that predicts streamflow from snowmelt.

The Soil Conservation Service has indicated a willingness to cooperate with the States of Wyoming and Montana in the development of forecasts that would mutually benefit both states and help administer the Yellowstone Compact. The SCS has identified the Clarks Fork Basin as a high priority watershed for fiscal year 1983, and in the near future, intends to draft a cooperative agreement to develop forecasts in the remaining basins.

It is suggested that any costs related to the collection of streamgage data continue to be divided: 25% Wyoming, 25% Montana, 50% USGS. Other costs should be divided equally between both states.

Potential Problems - Phase II

No problems are expected since the aquisition of hydrologic data and the development of forecasts are activities that could benefit both Wyoming and Montana.

Conclusion - Phase II

The capability of forecasting inflow to a river would significantly improve the manner in which individual water rights, as well as the Yellowstone Compact could be administered. Basin-wide water management and irrigation scheduling are dependent on accurate and timely forecasts of available water supply.

After a system of forecasting inflow has been developed, the next step in the administration of water rights involves the actual physical measurement of the quantity of water being appropriated. This activity is discussed in the following section.

Phase III - Determination of Irrigation Water Use

Objectives

The objectives of Phase III would be to educate water users concerning the importance of irrigation water measurement, to install proper headgates, measuring devices, and recorders on all major ditches and canals (The most common varieties of water measuring devices include weirs, flumes, and vane type flow meters. Examples of a number of different types of water measuring devices and the advantages and disadvantages of each are listed in Appendix D.), and to institute a centralized system of uniform record keeping. There is an urgent need to measure diversions and keep accurate records of water use for the following reasons:

1. The apportionment formula in Article V of the Yellowstone River Compact specifically requires these data [See 85-20-101, 105, 106 of Montana Code Annotated]. The measurement of irrigation water is a prerequisite to real-time Compact administration.
2. Adequate headgates and water measuring devices are needed to administer intrastate water rights and to admeasure water.

3. Water use data are required in order to accurately determine each state's historic share of allocable flow under the terms of the Yellowstone River Compact.
4. The protection of existing irrigation is important to both states. Therefore, this use needs to be accurately identified, measured, and recorded.
5. Water measurement is an integral component of irrigation scheduling and irrigation water management. From an agricultural and economic standpoint, irrigation scheduling and water measurement should provide many benefits to farmers and ranchers. It has been shown that seed germination and plant growth are negatively affected by over-watering. In addition, the erosion of the water-holding organic layer of soil contributes to decreased yields and increased sediment loads to streams. Water users, therefore, need to be aware that there is a financial incentive to managing and measuring the amount of water going to their fields.

A review of Compact Law, as well as Montana and Wyoming state law regarding the authority to measure water use may be found in Appendix E.

A Strategy for Determining Water Use in Montana

There are two basic strategies the State of Montana could use to promote irrigation water measurement:

Strategy A

Amend state statutes, or have the Board of Natural Resources adopt rules, that facilitate the enforcement of laws requiring water measurement and record keeping. (see 85-2-113-sub 2b, MCA).

Advantages:

1. This method produces quick results.
2. Data could be collected from every water user.
3. The new law, or adopted rule would apply statewide.

Disadvantages:

1. Government regulation is not popular.
2. The political feasibility of amending state law to enforce irrigation water measurement is questionable.
3. Measurement is costly.

Strategy B

Initiate a program through the Cooperative Extension Service to educate water users concerning the benefits of irrigation water measurement. The purpose of this program would be to explain how water-users can protect themselves under the terms of the Compact and thereby instill a grassroots demand for water measurement.

Advantages:

1. There would be a higher degree of community acceptance in measuring water use.
2. The educational process would most likely incorporate principles of irrigation water management and irrigation scheduling.
3. This method could result in increased agricultural productivity and decreased soil erosion.
4. Users would be documenting their use and protecting their rights through record keeping.

Disadvantages:

1. The process of education is expensive and slow.
2. Compliance is not mandatory.

3. The data resulting from this method would be incomplete.

Preferred Course of Action - Phase III

Analysis of the advantages and disadvantages of strategies A and B suggest that neither strategy would be sufficient by itself. Therefore, the preferred course of action should combine government regulation and public education in a manner that achieves the required results. The following activities are suggested:

Activity A

Develop and promote programs with the Cooperative Extension Service or other interested agencies to educate irrigators concerning Yellowstone Compact issues as well as the importance of irrigation water management and scheduling. The objective of these programs would be to increase community acceptance of measuring diversions and recording water use.

Activity B

After community acceptance has increased, develop rules to be adopted by the Board of Natural Resources which would require irrigation water measurement and record keeping.

Activity C

Assign the DNRC Water Rights Field Offices the responsibility of assisting ditch owners in sizing and installing proper headgates and measuring devices.

Activity D

Introduce legislation that would move the jurisdiction over water rights from the District courts to the DNRC Water Rights Bureau. The District courts would continue to have the power of judicial review, and handle any cases appealed to them.

Activity E

The Water Rights Bureau would set up a data file on diversions, and work directly with water commissioners and the Yellowstone River Compact Commission.

Potential Problems - Phase III

There are two areas of conflict that the State of Montana should be concerned with:

- a. The prevailing attitude concerning the measurement of diversions in the State of Montana.

- b. The political feasibility of moving the jurisdiction over decreed water rights administration from the district courts to the DNRC.

Conclusion - Phase III

Irrigation water measurement is one of the most critical issues to be resolved in the Yellowstone River Basin. Without the measurements and record keeping of actual water use in both states, the Yellowstone Compact will probably not be administered. In addition, because water rights administration is tied directly to measurement and adequate record keeping, this issue also has implications outside the Yellowstone Basin.

Two methods of implementing a system of water measurement have been suggested: government regulation and public education. Each has its inherent advantages and disadvantages, and for this reason a combination of education and legal action may prove to be the most effective strategy.

The general public needs to be made aware of the benefits of measuring their water use and a grassroots demand for this activity should be cultivated statewide. In addition, the education process should be subtle and proceed in a manner that paves the way for unified state administration. Such administrative activity would then provide a procedural framework and uniformity in rule making that could apply statewide.

Phases I, II, and III are concerned with water rights data organization, streamflow forecast development, and water measurement. The next step would be the formulation of a procedure that could be used by water commissioners to administer water rights on a real-time basis. This is the principle activity of Phase IV and will be addressed in the following section.

Phase IV - Intrastate Admeasurement and Interstate Communication

Objectives

The objectives of the fourth phase of this plan include the creation of an institutional and procedural framework with which to admeasure irrigation water in each state, transfer and store water use data between agencies in a particular state, and communicate this information between states. It is assumed that before water commissioners could admeasure water, the following criteria would have been satisfied:

- a. Water rights in each basin would be field-checked, verified, mapped, and then organized according to the headgate from which they originate.
- b. Functional headgates and accurate measuring devices would be installed in each ditch.
- c. Water rights data (ditch name, priority dates, flows) would be punched on metal tags and permanently fixed to each headgate.
- d. Streamflow forecasts would be developed for each basin.
- e. Each streamflow gage at the basin headwaters, state line, and compact point of measurement would have telemetry capability.

The actual need to proceed with Phases IV and V would be predicated on a demand to manage and regulate diversions in the Yellowstone Basin. This demand could come from any one of the following sources:

- a. Water users in either Wyoming or Montana might demand regulation due to a severe drought.
- b. Water users in Montana might demand interstate regulation in response to a water shortage induced by overdevelopment in Wyoming.
- c. Agencies of both state governments might require basin-wide water management if Wyoming began construction on large storage projects.
- d. Agencies of both state governments might require regulation if there was a bilateral exchange of water between tributaries in the Yellowstone Basin.
- e. The State of Montana would require regulation if permits were granted to Wyoming users for the appropriation of large quantities of water from the Yellowstone River mainstem.

The ability to admeasure water in Montana would depend on a number of factors; the most important of which would be the status of the current statewide adjudication process. For example:

- a. If a final decree has been issued on each tributary in the Yellowstone Basin and current state law concerning water rights regulation does not change, then 15% of the owners of the water rights, or the DNRC, could petition the district court(s) to appoint a water commissioner. In this case, the responsibility for the administration of intrastate water rights, as well as for the coordination of water rights related to interstate compact activities, would fall within Montana District Court jurisdiction.
- b. If a final decree has not been issued and current state law concerning water rights regulation does not change, there would be some question regarding the water commissioner's ability to effectively regulate non-adjudicated rights. In this case there is a high probability that the Yellowstone Compact could not be administered.
- c. If a final decree has been issued and the legislature transfers the court responsibility for administering

pre-1973 water rights to the DNRC, then all Compact and water rights related activities could be coordinated through this agency.

Preferred Course of Action - Phase IV

Activity A

Develop an organizational infrastructure that could administer and regulate water use on both an intrastate and interstate basis. If the Montana District Courts continue to have jurisdiction over water rights administration, there would be a need to define the limits of their responsibilities, and exactly how their activities would be coordinated with the Wyoming State Engineer's Office, the DNRC's Water Rights Bureau, and the Yellowstone River Compact Commission.

Activity B

There is a need for the administrative entities in charge of water use regulation in Montana and Wyoming to meet with the Yellowstone River Compact Commission for the purposes of:

1. Establishing a formal line of communications for in-field administration of the Compact.

2. Developing a procedure to compile and present water use data in a timely, systematic, and uniform manner.
3. Adopting any rules and regulations that would be used as a guide for in-field administration of water rights between states.

Activity C

Introduce legislation that would transfer the responsibility for administration of pre-1973 water rights from the Montana District Courts to the DNRC Water Rights Bureau. The ability to appeal a DNRC decision to judicial review would still be available. This change is suggested for the following reasons:

1. The Water Rights Bureau has experience in processing and verifying water rights claims and should therefore have a comprehensive understanding of water use in the Yellowstone Basin.
2. Water Rights Bureau personnel have worked with water users on an individual basis and have already established credibility and trust.
3. Administration of water rights via the Water Rights Bureau would not depend on legal actions or court proceedings. The total cost to initiate regulation would be less.

4. Water Rights Bureau Field Offices have already been established. Water rights data, and some of the equipment to access and analyze these data is in place and operational. Water commissioners and hydrographers would be able to work out of these offices.

Activity D

Introduce legislation that would give greater administrative control to Montana water commissioners for the regulation of reservoir storage. All requests for releases from storage should be coordinated with the water commissioner because:

1. The water commissioner would have to quantify inflow above diversions, as well as flows released from storage in order to properly regulate water rights that would be satisfied from natural flow, and rights that would be satisfied with stored water.
2. The water commissioner would be responsible for the quantification of $\Delta S(WYpre50)$ and $\Delta S(MTpre50)$ in the Compact allocation formula. (Equations #1 and #2). These terms represent the net change in storage in pre-1950 reservoirs used for post-1950 development in Wyoming and Montana.

Activity E

Once an organizational infrastructure is in place, the following rules and regulation would need to be adopted by the Compact Commission in order to administer water rights on an interstate basis:

1. At the beginning of the irrigation season, irrigators in both states would open their own headgates, set flows to the desired level, and measure diversions.
2. There would be no need to administer water rights on an interstate basis until a Montana irrigator on the mainstem of a stream which physically crosses the state line becomes short of water.
3. At this point, $Q(\text{allocWY})$ and $Q(\text{allocMT})$ would be quantified. These terms represent the quantity of water allocated to Wyoming and Montana, respectively, since October 1.
4. If the total accumulated flow in Wyoming $Q(\text{accumWY})$ is greater than the total allocable flow, Wyoming water use must be regulated to conform with the compact equation and satisfy as much of the Montana demand as possible. If not, the Montana irrigator would be regulated according to priority of right within the State of Montana, only.
5. Once the system is in equilibrium, the inflow and the divertable flow would be plotted on the river calibration curve. (See example and methodology in Appendix B).

Potential Problems - Phase IV

Water rights administration on a full time basis requires a large capital investment. For example, commissioners and hydrographers need transportation and communications equipment. Each office needs to have a copy of all relevant water rights data, aerial photographs and maps. In addition each office should be capable of referencing the central water rights computer file in Helena. Additional staff and such office equipment as typewriters, copy machines, etc. would be needed.

A potential conflict with Montana state law exists on how this equipment and its maintenance would be paid for. Montana Code Annotated (85-5-201 through 206) requires the water commissioner to keep a record related to only the following expenses:

1. "... reasonable expenses incurred by a water commissioner in telephoning to the judge for instructions in cases of emergency."
2. "... any expenses necessarily incurred by the water commissioner in the discharge of his duties in the employment of extra labor for the repair of dams, headgates, ditches, or flumes when immediate action is necessary...."

The law also requires the water commissioner to file a letter with the clerk of court concerning his expenses. This letter would be sent to all appropriators with an opportunity for their objections, a public hearing, and motions to retax. After the objection period, the court would fix and apportion these fees and expenses.

Conclusion - Phase IV

The sections of law pertaining to water commissioners, and their salaries and expenses are inadequate. In addition, the anticipated costs of water rights administration would preclude user taxation as a method of financing. Legislation should therefore be introduced that addresses these issues.

Phase IV has outlined a strategy to provide Montana with an organizational infrastructure to regulate water use on an intrastate basis. After both states are able to administer water rights on an intrastate basis, the final step would be administration of the Compact. Developing the Compact accounting computer model and resolving issues related to administration of the Yellowstone Compact are the principle activities of Phase V.

Phase V - Compact Administration

Objectives

The principle objective of Phase V is the development of a computer program (Compact Accounting Program) that could periodically evaluate the Compact apportionment and maintain such statistics as streamflow, diversions, reservoir operations, evaporation and water transfers. The Compact Accounting Program would be based on the equations that were introduced in Section III B of this report and would use initial input values of divertable flow obtained from the river calibration curves found in Appendix B. An example which ties together the ideas and methodology of Phases I through V is presented in Appendix G.

Preferred Course of Action - Phase V

Activity A

Decisions need to be made by the Yellowstone Compact Commission regarding what person(s) in which agency(ies) would be responsible for:

1. Coordinating activities related to the use and updating of the river calibration curve.
2. Developing computer software and documentation for the Compact Accounting Program.

3. Developing a user's manual for the Compact Accounting Program.

Activity B

The Compact Commission would need to decide:

1. In which state, and on what computer, the Compact Accounting Program would be stored and how the development of this program would be financed.
2. What person in which state would run and maintain the accounting program.
3. How this person's salary, computer processing, and related expenses would be financed.

Activity C

The Compact Commission would need to adopt rules and regulations that would formalize communications and procedures relating to the coordination of the following activities:

1. Generation of streamflow forecasts.
2. Construction of the river calibration curve.
3. Prediction of divertable flow.
4. Petitioning Montana district courts to regulate diversions.

5. Regulation of headgates.
6. Reservoir operations.
7. Organization and storage of data.
8. Running the Compact Accounting Model.

Potential Problems - Phase V

There are a number of Compact-related issues that need to be resolved in order to administer the Yellowstone Compact on a real-time basis. These issues include:

- a. Allocation of Non-Irrigation Season Flow and Excess Spring Flow (Assuming No Reservoir Storage)

For purposes of this report, flows during the non-irrigation season and excess spring flows shall be defined as that excess flow which passes the compact point of measurement from October 1st to the first day during the irrigation season when water is admeasured on an interstate basis. This flow is physically unavailable during the irrigation season; it is not in the stream, it has not been stored, and it therefore cannot be "allocable flow". For administrative purposes, this water could be moved to an "unused and presently unavailable" account. Statistics from this account would be useful for sizing new reservoir projects and determining firm yields.

The adjustment described above would have the effect of zeroing out the term Q (compact gage) in Equation 3 until there was a demand on the system to regulate water rights on an interstate basis. Return flows generated below the last diversion in Montana and above the point of measurement would also be subtracted from the Q (compact gage) flow, since this flow is physically unavailable upstream.

An example explaining why this adjustment would be important on streams which have no reservoir storage, and how this adjustment would work can be found in Appendix F.

b. Indian Reserved Water Rights

Would an interpretation of Article VI of the Compact imply that Indian reserved water rights are to be subtracted from the total allocable volume, or are they chargeable to the state in which the use occurs?

c. Supplemental Water

The Compact Commission would need to adopt a regulation defining "supplemental water". It is suggested that a version of the following definition be adopted:

"Supplemental water, for purposes of administering the Yellowstone River Compact, shall be defined as that

quantity of water having a post-1950 priority which is appropriated for the purpose of bringing a full supply to land already irrigated with water having a pre-1950 priority." Definition of the term "full supply" should be standardized in both Wyoming and Montana.

d. Operation and Administration of Water from Interstate Reservoirs.

Reservoirs located on the state line present special problems in the determination of $\Delta S(WY \text{ pre}50)$ and $\Delta S(MT \text{ pre}50)$. For example, how would evaporation be charged? The Bureau of Reclamation operates Yellowtail Reservoir to optimize hydroelectric power production. How does this fit into the Article V apportionment?

e. Apportionment of Non-Compacted Return Flows

Return flows via wasteways from non-compacted streams (i.e., Rock Creek in the Clarks Fork Basin) empty into compacted streams (i.e. Clarks Fork River mainstem). Presently, this flow would be considered "allocable" because it would either be diverted or it would flow past the point of measurement. How will cases like this be handled administratively?

f. Protection of Instream Flows

Minimum flow standards for the protection of aquatic habitat in the Yellowstone River Basin have already been adopted by the State of Montana. It is likely that Wyoming may soon adopt similar standards. Instream uses of water present special problems for administration of the Yellowstone Compact because Article V apportions all water flowing past the point of measurement. It is suggested that as soon as Wyoming adopts instream flow standards in the Yellowstone Basin, all instream flows be protected from apportionment under the terms of the Compact. To do this, the Compact Commission might adopt rules or regulations that would have the effect of subtracting the appropriate instream flow from the flow at the point of measurement and then transferring it to an "unused and presently unavailable" account. Another example of how the Compact Commission could protect instream flows is presented in Appendix H.

Conclusion - Phase V

Phase V emphasizes the importance of developing a Compact Accounting program as well as resolving a number of issues affecting the Yellowstone Compact apportionment. It is suggested that a timetable be developed by the Compact Commission to resolve these issues through negotiation rather than through litigation.

IV. CONCLUSION

Records of actual water use are necessary in order to administer the Yellowstone River Compact, to make a determination of Montana's historic share of allocable flow, and to protect existing irrigation in the Yellowstone Basin. Therefore, the management plan presented herein stresses the importance of providing the State of Montana with an institutional framework to promote water measurement and accurate record keeping.

Suggestions have been presented which would affect Montana state law regarding jurisdiction and procedures pertaining to water rights administration, admeasurement, and regulation. In addition, a method is proposed whose purpose is to forecast inflow and total divertable flow, and to assist water commissioners in the day-to-day administration of water rights on an intrastate and interstate basis.

It is now up to the Wyoming and Montana legislatures, and the Yellowstone River Compact Commission to decide if the Compact needs to be administered and when a system of water measurement should be implemented.

APPENDIX A - SUMMARY OF ARTICLE V OF THE YELLOWSTONE RIVER
COMPACT

- A. The Compact does not affect the enjoyment of appropriative rights existing in each state as of January 1, 1950.
- B. Of the unused and unappropriated waters as of January 1, 1950, each State is allowed supplemental water for the rights existing as of January 1, 1950. The remaining unused and unappropriated waters are allocated to each State:
1. Clarks Fork - 60% WY, 40% MT;
 2. Bighorn River (Exclusive of Little Bighorn River) - 80% WY, 20% MT;
 3. Tongue Rier - 40% WY, 60% MT; and
 4. Powder River (Including the Little Powder River) - 42% WY, 58% MT.
- C. The quantity of water to be allocated by the percentages is on an October 1 - September 30 water year basis. The quantity, in acre-feet, is the algebraic sum of:
1. Total diversions for irrigation, municipal, and industrial uses in Wyoming and Montana developed after January 1, 1950 from October 1 to calculation date.

2. Net change in storage in all reservoirs in Wyoming and Montana completed after January 1, 1950 from October 1 to the calculation date.
3. Net change in storage in existing reservoirs (as of January 1, 1950) used for irrigation, municipal, and industrial purposes developed after January 1, 1950 from October 1 to the calculation date.
4. The quantity of water that passed the point of measurement in the stream from October 1 to the calculation date.

D. (Addresses Montana - North Dakota allocations)

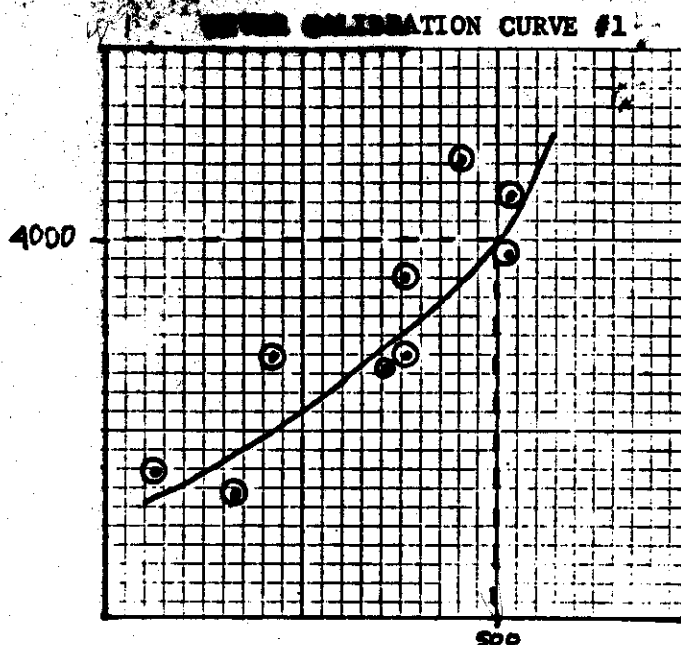
E. Excludes:

1. Domestic and stockwater uses, provided that the capacity of an excluded stockwater reservoir does not exceed 20 acre-feet.
2. "Devices and facilities for the control and regulation of surface waters."

F. (Allows modifications of allocations under certain conditions.)

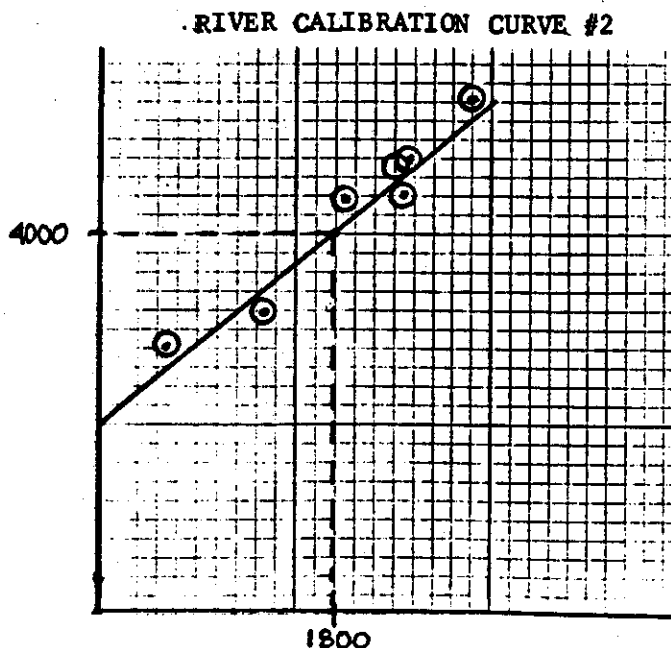
APPENDIX B - SAMPLE CALIBRATION CURVES AND EXPLANATIONS

AVERAGE RATE OF INFLOW
ABOVE DIVERSIONS FOR
THE ACCOUNTING PERIOD
IN CFS



DIVERTABLE FLOW IN CFS THAT CAN
BE ALLOCATED ON A PERCENTAGE
BASIS

AVERAGE RATE OF INFLOW
ABOVE DIVERSIONS FOR
THE ACCOUNTING PERIOD
IN CFS



AVERAGE STATE LINE FLOW
FOR THE ACCOUNTING PERIOD
IN CFS

Explanation of Calibration Curve #1

Abscissa - The total post-1950 divertable flow to be allocated on a percentage basis between Wyoming and Montana.

Ordinate - The average inflow to the river system in cubic feet per second for the accounting period (7 days).

Inflow is measured above diversions on the mainstem, and on all major tributaries.

Example - Clarks Fork Basin

At the beginning of day 1 of the compact accounting period, the measured inflow above diversions was 3500 cfs. By the end of the accounting period, the measured inflow is 4500 cfs. Assuming a constant rate of increase, the average inflow for this period is 4000 cfs.

Next, assume that pre-1950 users in both Wyoming and Montana can be satisfied and that, after regulation of post-1950 uses, there is approximately 500 cfs of divertable flow recorded. In the Clarks Fork Basin, the split is 60% (Wyoming) - 40% (Montana). Therefore, for this accounting period, headgates are regulated so that there is only 300 cfs of diversions in Wyoming and 200 cfs of diversions in Montana.

Calibration curve #1 serves two functions. First, data derived from actual system operation at the end of the accounting period is plotted. The curve is calibrated with actual measured inflow and actual diversion data. Second, the curve can be used as a predictive tool. Forecasted inflow can predict projected level of use for the upcoming accounting period. The projected level of divertable flow would be used as input for the initial run of the Compact Accounting Program to determine the apportionment.

How to Use Curve #1

(Assume accounting period is from day N to day N + 7)

1. On day N-3, the average inflow above diversions for day N through day N+7 would be predicted.
2. Enter curve #1 with this value and read off divertable flow for post-1950 uses.
3. Apply compact percentage, and calculate divertable flow for each state. "Divertable flow" in each state would translate to a specific priority date or level of use for which water would be regulated. The values for inflow, divertable flow, and return flows could be tested in the Compact Accounting Program at the beginning of each accounting period.

4. Use these values of divertable flow in the initial run of the Compact Accounting Program to determine whether the values chosen conform with the terms of the apportionment. If not, rerun with new values of divertible flow.
5. Water Commissioners in each state would then set headgates on day N to correspond to this level of use.
6. If there is any excess flow at the point of measurement which could be used upstream, headgates would be readjusted accordingly.
7. At the end of the accounting period the Compact Accounting Program would be rerun with actual values for diversions, and actual inflow versus actual divertable flow would then be plotted on calibration curve #1.
8. Steps 1 through 7 would be repeated for each accounting period.

Note: Calibration curves do not take into account water released from reservoirs. This is considered to be a separate issue. Also, the temporal distribution of return flow may indicate that a distinct calibration curve may be needed for each month.

Explanation of Calibration Curve #2

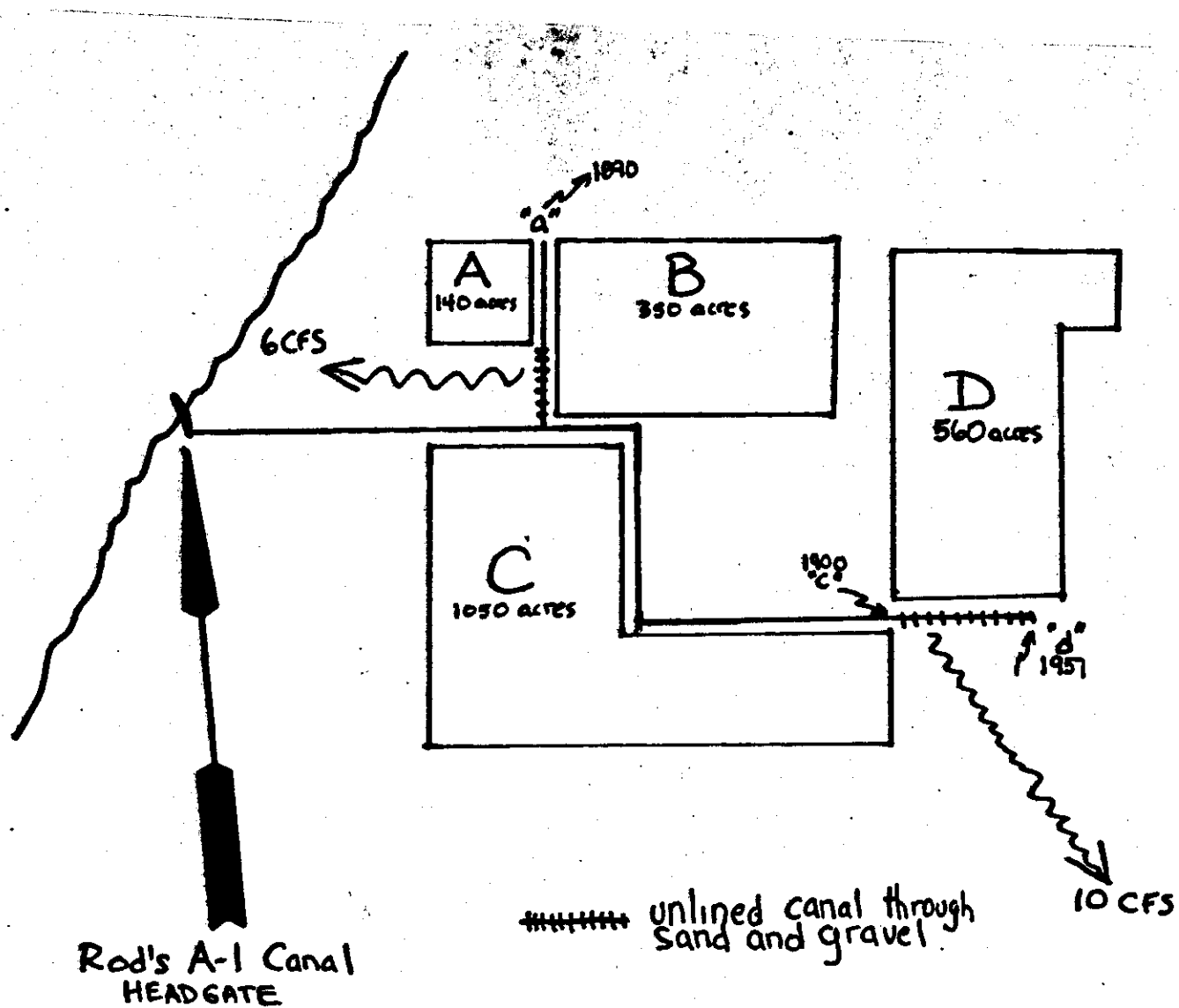
Abscissa - average streamflow at the state line for the accounting period needed to satisfy all pre-1950 users plus any post-1950 uses indicated by calibration curve #1.

Ordinate - average rate of inflow above diversions for the accounting period.

Calibration curve #2 is an extension of curve #1. For the example presented, 4000 cubic feet per second is the measured inflow above diversions. All pre-1950 appropriators are satisfied and there is a total of 500 cubic feet per second of diversions for post-1950 uses. There is little excess flow at the point of measurement. Calibration curve #2 indicates that under these conditions, 800 cubic feet per second should cross the state line. Calibration curve #2 and streamgauge telemetry are necessary to insure that Montana receives its share of Compact water at the state line. This flow would probably be monitored on a daily basis during critical low flow periods.

APPENDIX C - WATER RIGHTS EXAMPLE

Exhibit 1: Sketch of Rod's A-1 Canal Company



History of Actual Use During Years of Surplus Water
(Canal located in Wyoming or Montana)

<u>Year</u>	<u>Ditch Capacity</u>	<u>Ditch Completed to Point</u>	<u>Lands Irrigated</u>	<u>Actual Use</u>
1890	15 cfs	a	A	10 cfs diverted 6 cfs lost through leaky canal 4 cfs applied to field A
1910	35 cfs	c	A,B,C	35 cfs diverted 6 cfs lost through leaky canal 4 cfs applied to field A 10 cfs applied to field B - full supply 15 cfs applied to field C - 1/2 supply
1951	80 cfs	d	A,B,C,D	76 cfs diverted 6 cfs lost to system 4 cfs applied to field A 10 cfs applied to field B 30 cfs applied to field C 10 cfs lost to system 16 cfs applied to field D

APPENDIX C - Exhibit 2

Example of Water Rights Filings for Rod's A-1 Canal Company

Wyoming Filings

Note: The water rights have been adjudicated by the Wyoming Board of Control and are listed in a document entitled Tabulation of Existing Water Rights of the State of Wyoming. During a water shortage, water used by Rod's A-1 Canal Company is regulated by a water commissioner according to these rights.

<u>Permit No.</u>	<u>Priority</u>	<u>Flow (C.F.S.)</u>	<u>Acres</u>
1000	1890	4.0	140
Enlargement 1	1910	10.0 (full supply) + 15.0 (half supply) 25.0	350 + 1050 1400
Enlargement 2	1951	10.0 (supplemental for C) + 8.0* 18.0	--- 560
TOTAL		47.0 cfs	2100 acres

*Note: Priorities earlier than 1945 get 2 cfs/70 acres
Priorities later than 1945 get 1 cfs/70 acres

Montana's Filings

<u>Claim #</u>	<u>Priority Date Claimed</u>	<u>(C.F.S.) Flow Rate Claimed</u>	<u>Acres Claimed</u>	<u>Type of Right</u>
1000	1890	15	140	Decreed
1001	1910	25	1400	Use
1002	1951	40	1610	Filed
TOTAL		80	3150	

APPENDIX C - Exhibit 3

Examples of Master Ditch Lists

<u>Wyoming</u>			<u>Montana</u>		
Ditch No. 001			Ditch No. 001		
Name: Rod's A-1 Canal Co.			Name: Rod's A-1 Canal Co.		
Headgate location:			Headgate location:		
Ditch Capacity: 80 cfs			Ditch Capacity: 80 cfs		
Acres Served: 2100			Acres Served: 2100		
Water Rights: Permit 1000			Water Rights: Claim 1000		
Enlargement 1			Claim 1001		
Enlargement 2			Claim 1002		
<u>Type</u>	<u>Priority</u>	<u>Flow</u>	<u>Type</u>	<u>Priority</u>	<u>Flow</u>
A	1890	4.0 cfs	A	1890	15 cfs
A	1910	25.0 cfs	A	1910	25 cfs
A,S	1951	10.0 cfs	A,S	1951	15 cfs
B	1951	8.0 cfs	B	1951	25 cfs
TOTAL PRE-1950: 39 cfs			TOTAL PRE-1950: 55 cfs		
TOTAL POST-1950: 8 cfs			TOTAL POST-1950: 25 cfs		

Key

A = Pre-1950

B = Post-1950

S = Supplemental (defined as that water needed to bring land irrigated prior to 1950 up to a full supply)

APPENDIX C - Exhibit 4

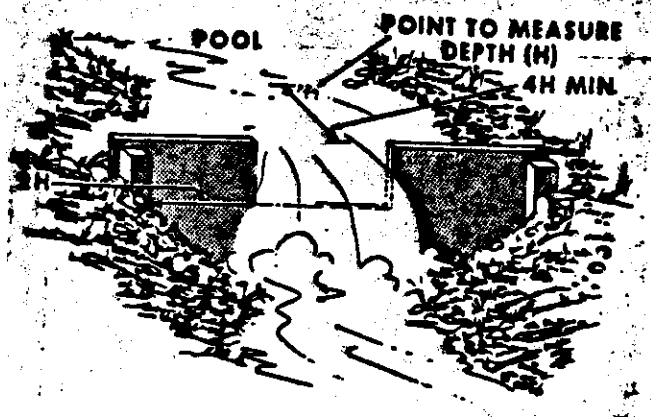
Example Headgate Tags for Rod's A-1 Canal Company

DITCH NO. 001		
ROD'S A-1 CANAL CO. (Wyoming)		
<u>DOCUMENT</u>	<u>PRIORITY</u>	<u>FLOW</u>
1000	1890	4 cfs
E-1	1910	25 cfs
E-2	1951	10 cfs
E-2	1951	8 cfs

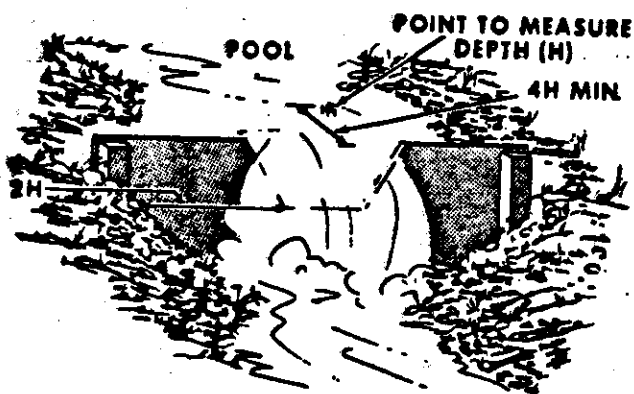
DITCH NO. 001		
ROD'S A-1 CANAL CO. (Montana)		
<u>DOCUMENT</u>	<u>PRIORITY</u>	<u>FLOW</u>
1000	1890	15 cfs
1001	1910	25 cfs
1002	1951	15 cfs
1002	1951	25 cfs

APPENDIX D - EXAMPLES OF WATER MEASURING DEVICES

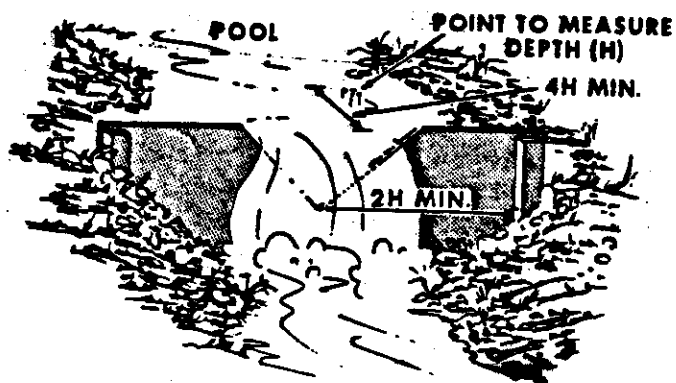
Drawings adapted from Irrigation Water Measurement, Agricultural Extension Service, UW-Laramie



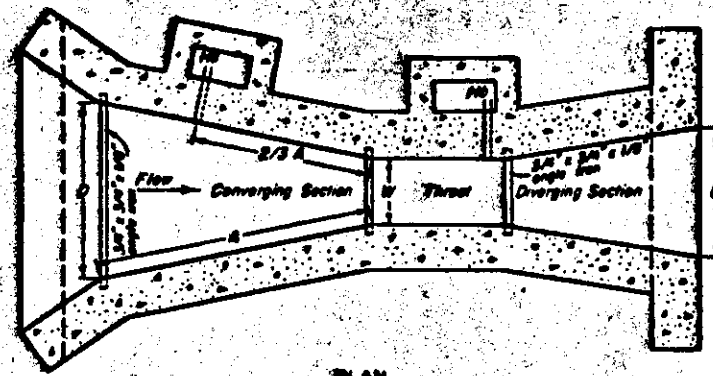
RECTANGULAR WEIR



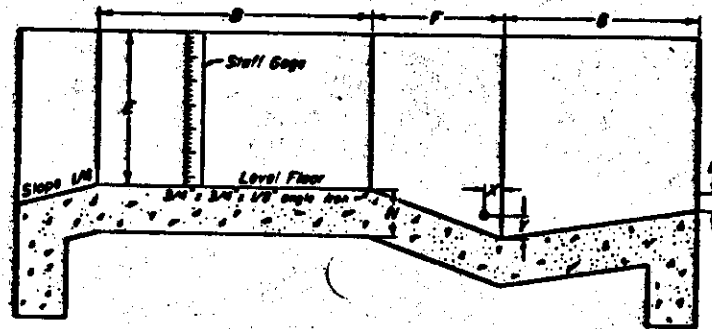
TRAPEZOIDAL WEIR



V-NOTCH WEIR

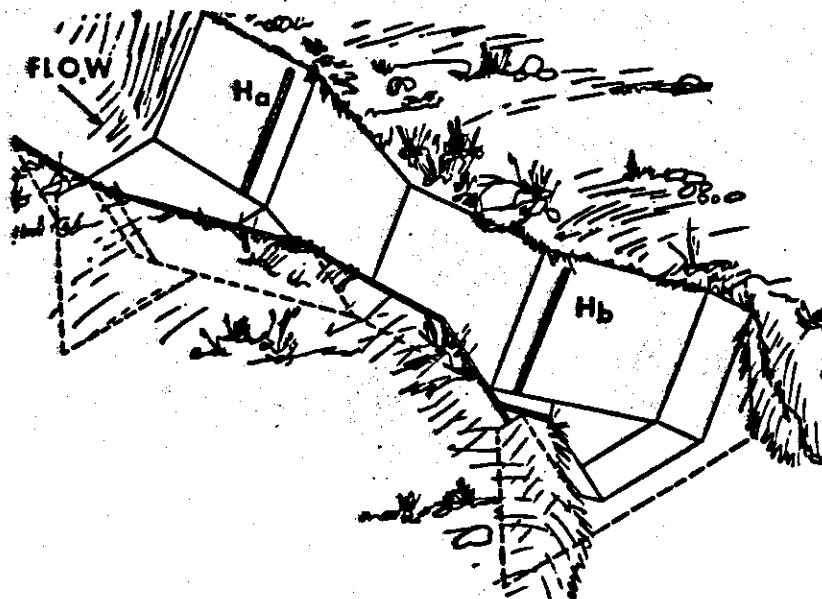


PLAN

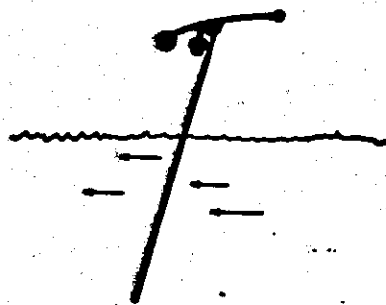
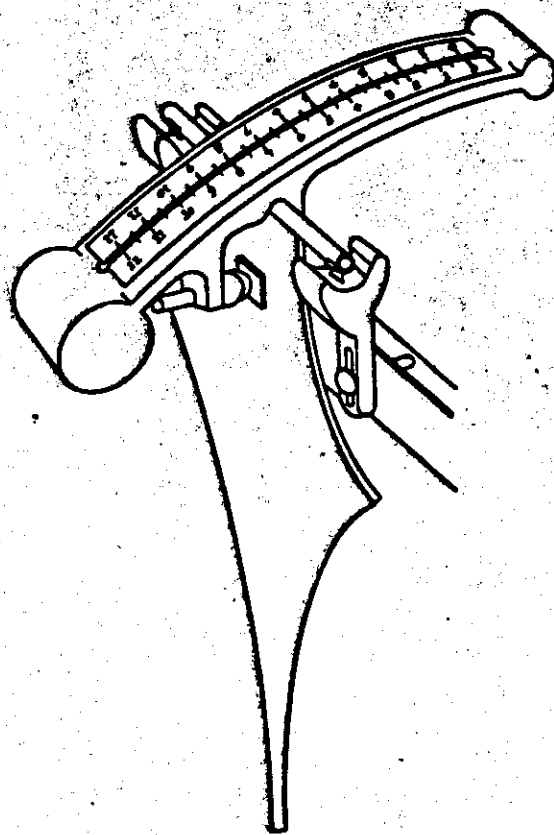


SECTION

PARSHALL FLUME



TRAPEZOIDAL FLUME



VANE-TYPE FLOW METER

(A) Weirs - (rectangular, Cipolletti, V-notch)

Advantages:

1. Weirs are simple to construct.
2. Weirs are convenient to use.

Disadvantages:

1. Weirs are not accurate unless they are properly installed and maintained. (the pool of water behind a weir often fills up with sand and silt).
2. Weirs require a considerable drop between the upstream and downstream water surfaces. This may not be possible where ditches are on a nearly level grade.
3. Weirs are not easily combined with turnout structures.

(B) Flumes (Parshall, Trapezoidal)

(Parshall Flume)

Advantages:

1. Parshall flumes are durable and require little maintenance.
2. Parshall flumes are very accurate.
3. Sand and silt in the irrigation water do not affect the performance of a Parshall flume.
4. Parshall flumes do not require a large change in head between the upstream and downstream water surfaces.
5. The rate of flow through the Parshall flume does not affect its accuracy.
6. The Parshall flume has a wide range of flow capacity.
7. Pre-fabricated Parshall flumes are available commercially.

Disadvantages:

1. Parshall flumes are more costly than weirs.
2. Parshall flumes are more difficult to install.

(Trapezoidal flumes)

Advantages:

1. Trapezoidal flumes are easy to construct and install.
2. Trapezoidal flumes do not require a large change in head.
3. The trapezoidal flume can handle a large range of flow.

Disadvantages:

1. Trapezoidal flumes are not as accurate as Parshall flumes because a very small change in head results in a very large change in flow.

(C) Vane type flow meters

Advantages:

1. Vane flow meters are portable and can be used to measure flow on a number of canals.
2. Vane flow meters are easy to install.
3. Vane flow meters give direct readings in cfs.

Disadvantages:

1. Wind affects the accuracy of vane flow meters.
2. Vane flow meters are not inexpensive.

APPENDIX E - LAWS REGARDING THE DETERMINATION OF IRRIGATION WATER
USE

Status of Water Measurement - Compact Law

The issue of irrigation water measurement is addressed in Article I, paragraph B, of the "Rules and Regulations for Administration of the Yellowstone Compact". This paragraph states that "Records of total annual diversion in acre-feet above the points of measurement designated in the Compact for irrigation, municipal, and industrial uses developed after January 1, 1950, shall be furnished by the members of their respective States, at such time as the commission deems necessary for interstate administration as provided by the terms of the Compact." In addition, both the Yellowstone Compact and administrative rules state that the "appropriative rights to the beneficial uses of water ... existing in each signatory state as of January 1, 1950, shall continue to be enjoyed...."

It would therefore be reasonable to infer the following:

1. The Yellowstone Compact and administrative rules require that diversions with a priority date later than January 1, 1950 must be measured.

2. For record keeping and accounting purposes, diversions with a priority date earlier than January 1, 1950, should be measured.

Status of Water Measurement - Wyoming Law

The Wyoming State Engineer and the superintendents of the four water districts constitute the Wyoming Board of Control. The Board has the power to regulate water use, and can supervise the diversion, distribution, and appropriation of water from all streams. A water commissioner appointed by the Governor has the responsibility of dividing water and regulating reservoir storage on all streams in his division.

Wyoming state law requires the owner of any canal or ditch to install and maintain a headgate at the point of diversion which is of such construction that it may be locked and kept closed by a water commissioner. Metal, screw-type headgates set in concrete are recommended.

At the request of the Division Superintendent, owners of canals or ditches must install and maintain flumes and other measuring devices to assist the commissioner in determining the amount of water being diverted. Any person who neglects to construct or maintain headgates, flumes, or measuring devices may be denied water until the required works are constructed.

Any person opening, closing, or changing any headgate or water box without proper authority, or who uses water which has been denied to him by a water commissioner can be arrested and fined.

Admeasurement of water in the State of Wyoming proceeds according to the following sequence of events:

1. At the beginning of each irrigation season, irrigators open their own headgates, and water use on the stream is unrestricted.
2. Water use is unrestricted until the water commissioner receives a call that an appropriator is not receiving his legal entitlement.
3. At that point, hydrographers measure inflow to the stream and then regulate headgates along its entirety according to priority of right. Headgates are set and locked in position.
4. Wyoming state law provides that priorities earlier than 1945 may receive two cubic feet per second (cfs) per seventy acres irrigated. Priorities later than 1945 receive one cfs per seventy acres.

5. If after regulation of headgates along the entire stream the water commissioner finds there is an excess water, this water is presently divided among Wyoming irrigators according to priority of use without regard to the terms of the Yellowstone Compact.
6. Inflow to the river system is measured throughout the irrigation season, and headgates along the entire stream and all tributaries are continually regulated.

Status of Water Measurement - Montana Law

Except for some permits issued after 1973, the State of Montana does not require the owners of canals and ditches to maintain measuring devices or keep records of diversions. However, a water commissioner may be appointed by a district court to admeasure and distribute water when one of the following conditions arise:

1. The owners of at least 15% of the water rights affected by a decree, petition the court to administer the decreed rights.
2. The DNRC requests the court to administer rights on a stream for which a final decree has been issued under Chapter 2, Title 85. (i.e. the Powder River).

There are a number of practical problems with the present system of adjudication and the measurement of irrigation water in Montana. Some of these include:

1. Many court decrees require that the owners of canals and ditches maintain water measuring devices and keep accurate records of diversions, yet these requirements are usually not enforced.
2. Only specific reaches are covered by any particular court decree and often there have been many decrees issued on one "decreed" stream. In spite of this, the majority of water users on a stream do not have an adjudicated right and will have to wait until the statewide adjudication process is complete.
3. Water commissioners have no jurisdiction to regulate pre-1973 water rights which have not been adjudicated. Therefore, there are cases where downstream senior water rights may be denied water because upstream junior rights cannot be regulated.
4. Any particular river basin may be under the jurisdiction of a number of district courts. For example, five district courts have jurisdiction in the Clarks Fork basin. Therefore, coordination of a uniform system of measurement, record keeping, and headgate regulation would be difficult.

APPENDIX F - ALLOCATION FORMULA EXAMPLE - NO RESERVOIR STORAGE

Figure 1 presents an example of the Yellowstone Compact Apportionment based on the equations presented on pages 10 and 11 assuming no reservoir storage is available (e.g. Clarks Fork Basin). In this example, allocable flow is calculated for Wyoming and Montana using two methods. "Method 1" does not adjust for the "unused and presently unavailable" flow passing the Compact point of measurement during the non-irrigation season. "Method 2" makes this adjustment.

In calculating historic allocable flow for both states, the adjustment is not necessary because one would be trying to quantify the flow that could have been used by each state. On the other hand, once that Yellowstone Compact is administered on a real time basis, flow that passes the compact point of measurement (and leaves the system) is no longer available for use at a later point in time. This flow should not be considered "allocable" because it is really "unused and presently unavailable." In this case, the adjustment would be necessary.

Exhibit 1 presents both versions of calculating allocable flow. There are twelve rows, each summarizing one month of data, and there are fourteen columns:

- Column 1: The present month.
- Column 2: Inflow, in 1000 acre-feet above all diversions.
- Column 3: The flow, in 1000 acre-feet passing the Compact point of measurement for that particular month.
- Column 4: The Compact gage "adjustment" in 1000 acre-feet needed to account for water that is "unused and unavailable" during real-time Compact administration.
- Column 5: The accumulated flow in 1000 acre-feet that passes the Compact point of measurement from October 1 to the last day of the present month. This is the last term in Equation #3.
- Column 6: The adjusted accumulated flow in 1000 acre-feet that passes the Compact point of measurement from October 1 to the last day of the present month. This value would be substituted in the last term of Equation #3 to calculate the adjusted allocable flow for each state.
- Column 7: The total diversions in 1000 acre-feet in Wyoming for the present month.
- Column 8: Equivilant to the left-hand-side of Equation #1.
- Column 9: The total diversions in 1000 acre-feet in Montana for the present month.
- Column 10: Equivilant to the left-hand-side of Equation #2.
- Column 11: Equivilant to the left-hand-side of Equation #4.
- Column 12: The adjusted allocable flow in 1000 acre-feet for Wyoming.

Column 13: Equivilant to the left-hand-side of Equation #5.
Column 14: The adjusted allocable flow in 1000 acre-feet for Montana.

The example presented in exhibit 1 assumes the following:

- a. Flow is apportioned 60% to Wyoming and 40% to Montana.
- b. There is no reservoir storage in the basin.
- c. All pre-1950 uses for irrigation are satisfied May through August.
- d. For the period of May through August there are 100,000 acre-feet of post-1950 demands in each state each month. One-half is for agriculture, the other half is for industrial off-stream storage. Each state tries to satisfy as much of this demand as possible.
- e. The example presented is a typical "dry year." While all pre-1950 uses can be satisfied, Wyoming post-1950 demands can not be met after June 1, and Montana post-1950 demands can never be fully met.

The following conlcusions can be drawn from this example:

1. The unused inflow from October 1 to April 30 is 116,000 acre-feet. If this flow is reflected in the Article V apportionment formula, the total allocable flow for May is too high. It is also unfair, because in May, Montana is receiving only 20% of the total divertable flow.

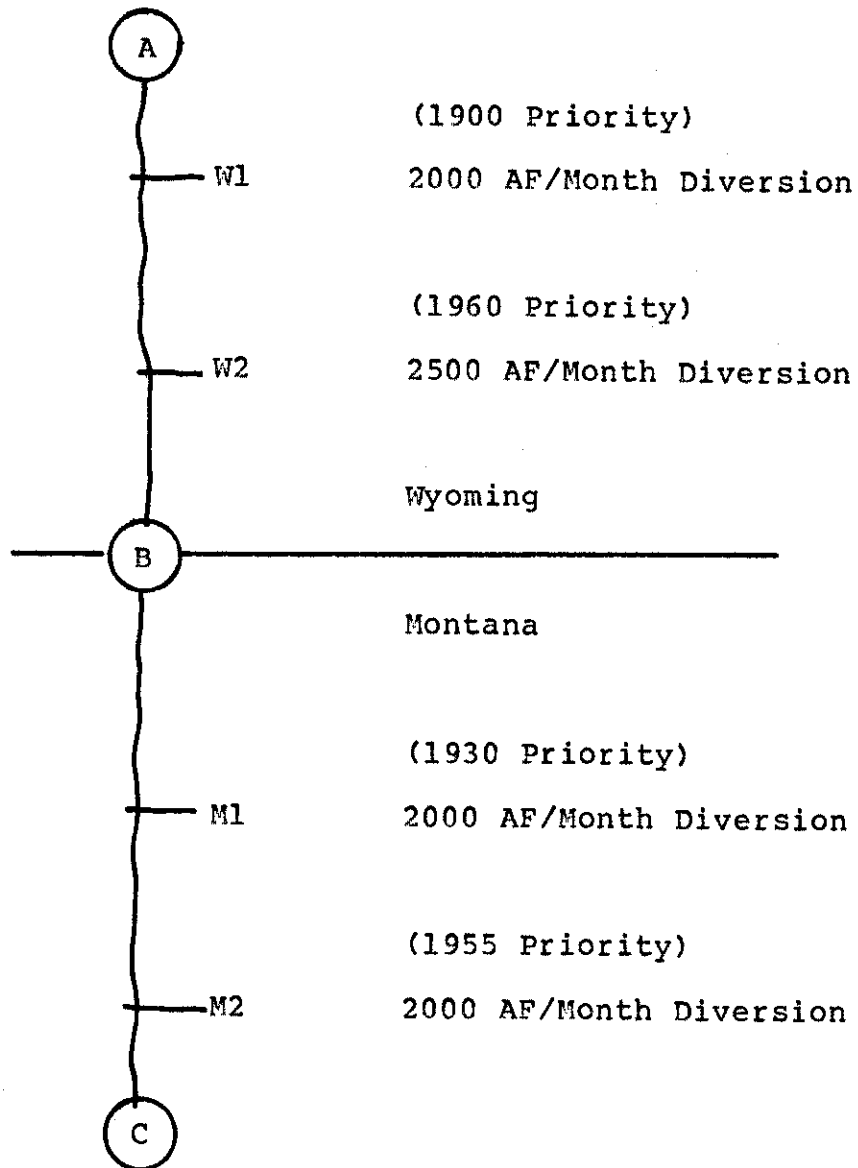
2. If the 116,000 acre-feet of inflow is moved to an "unused and presently unavailable" account, and the accumulated flow at the point of measurement is adjusted to reflect this, the adjusted allocation makes much more sense. Each state receives a reasonable allocation in May. In this example, Wyoming's post-1950 diversions in May were too high and therefore should have been regulated.
3. The "unused and presently unavailable" adjustment is needed in the Yellowstone Compact allocation formula, at least for real-time administration, because the State of Wyoming would benefit unfairly from water that was "stored on paper" and not stored in a reservoir.

YELLOWSTONE RIVER COMPACT APPORTIONMENT
(Assuming no Reservoir Storage)

All Values in 1000 Acre-feet

Month	Inflow per Month	Q (compact gage) per month	ADJUSTMENT (used and presently unavailable)	$\sum Q$ (compact gage) unadjusted	$\sum Q$ (compact gage) ADJUSTED	D (WY)	$\sum Q$ (accum WY)	D (MT)	$\sum Q$ (accum MT)	Q (alloc WY)	Q (alloc WY) ADJUSTED	Q (alloc MT)	Q (alloc MT) ADJUSTED	
COL	1	2	3	4	5	6	7	8	9	10	11	12	13	14
OCT	18	18	18	-18	18	0					10.8	0	7.2	0
NOV	18	18	18	-18	36	0					21.6	0	14.4	0
DEC	15	15	15	-15	51	0					30.6	0	20.4	0
JAN	14	14	14	-14	65	0					39.0	0	26.0	0
FEB	13	13	13	-13	78	0					46.8	0	31.2	0
MAR	13	13	13	-13	91	0					54.6	0	36.4	0
APR	25	25	25	-25	116	0					69.6	0	46.4	0
MAY	75	0	0		116	0	100	100	20	20	141.6	72	94.4	48
JUN	50	0	0		116	0	75	175	15	35	195.6	126	130.4	84
JUL	25	0	0		116	0	20	195	0		207.6	138	138.4	92
AUG	20	0	0		116	0	0				207.6	138	138.4	92
SEP	18	18	18	-18	134	0					218.4	138	145.6	92

APPENDIX G - COMPACT ADMINISTRATION EXAMPLE



A = inflow above diversions

B = state line flow

C = flow at point of measurement

W1, W2, M1, M2 are Wyoming and
Montana diversions.

Assumptions

1. There is no reservoir storage in the basin.
2. No water flows past the point of measurement and no water is consumptively used for the period October 1 to April 30.
3. The diversion requirement for W1, W2, M1, and M2 are constant for the period May 1 to September 30.
4. Exactly 1/2 of the quantity diverted returns to the stream as return flow. 100% of this flow returns the same month it is diverted.
5. Return flow from M2 comes in below the point of measurement.
6. All pre-1950 priorities in Montana must be satisfied prior to any post-1950 priorities in Wyoming.
7. The Compact apportionment is calculated on a monthly basis and all calculations are in acre-feet/month.
8. For the period May 1 to September 30, the inflow above diversions is equal to:

May	-	6000 acre-feet
June	-	4000 acre-feet
July	-	3200 acre-feet
August	-	2000 acre-feet
September	-	100 acre-feet

9. Montana receives 40% of the allocable flow
Wyoming receives 60% of the allocable flow

10. Assume both states appropriate water according to the rules of higher priority: "1st in time, 1st in right".

Explanation

The following activities summarize a suggested methodology for administering the Yellowstone Compact for the period May 1 to July 31.

1. Month of May

Activity A

The inflow above diversions is forecasted for the month of May and is equal to 6000 acre-feet per month.

Activity B

The river calibration curve (not shown) indicates that when the inflow above diversion is equal to 6000 acre-feet, all pre-1950 and post-1950 appropriations in both states can be satisfied. Prior to the first day in May, use an accounting model to solve the compact apportionment with the following input (exhibit 1):

inflow	=	6000 AF
W1	=	2000 AF
W2	=	2500 AF
M1	=	2000 AF
M2	=	2000 AF

Results of the accounting model first iteration suggest the apportionment can be satisfied for the month of May without the need for regulation.

Activity C

Headgates are opened May 1st on all pre- and post-1950 diversions in both states. Water use is measured and recorded.

Activity D

At the end of the month of May, rerun the compact accounting model with input equal to actual water use. Plot new points on the calibration curve.

2. Month of June

Activity A

The inflow above diversions is forecasted for the month of June and is equal to 4000 acre-feet per month.

Activity B

The calibration curve indicates that when the inflow above diversions is equal to 4000 acre-feet, approximately 7000 acre-feet of diversions can be satisfied. Prior to June 1, run the accounting model with the following input (exhibit 2):

inflow	=	4000 AF
W1	=	2000 AF
W2	=	2000 AF
M1	=	2000 AF
M2	=	1000 AF

Results of the Compact accounting model suggest the apportionment can be satisfied when W2 and M2 are regulated as indicated above.

Activity C

Water commissioners in both states regulate water use according to the results of the water model.

Activity D

At the end of the month of June, rerun the compact accounting model with input equal to actual water use. Plot these new points on the calibration curve.

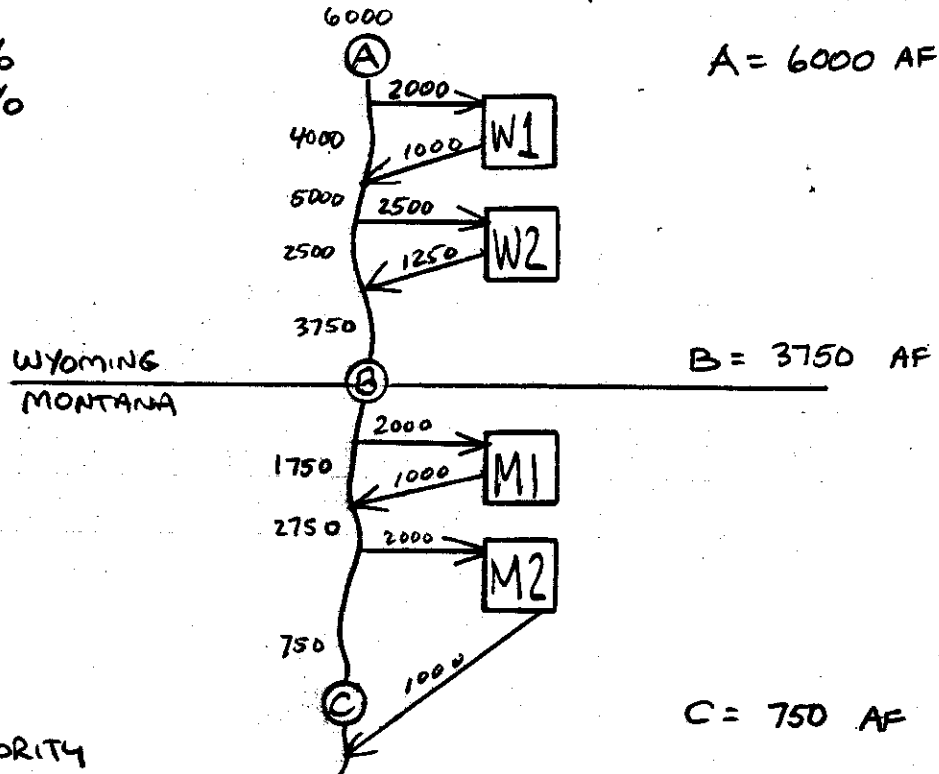
3. Month of July

The same methodology presented for the months of May and June apply in July. Note that even though $Q(\text{accumWY}) < Q(\text{allocWY})$ and $Q(\text{accumMT}) > Q(\text{allocMT})$, post-1950 water use in Wyoming must be regulated to satisfy pre-1950 water rights in Montana. In the example presented in exhibit 3, a minimum of 2000 acre-feet per month must cross the state line before post-1950 appropriators in Wyoming can divert water.

EXHIBIT 1

YELLOWSTONE COMPACT ALLOCATION FOR THE MONTH OF MAY

MONTANA = 40%
WYOMING = 60%



* = POST-KSO PRIORITY

STREAMFLOW FORECAST = 6000 AF
W1 = 2000 AF
* W2 = 2500 AF
M1 = 2000 AF
* M2 = 2000 AF

SUM FROM PREVIOUS MONTHS	TERM	ED(WY) ED(MT)	ΔS(WY POST-50) ΔS(MT POST-50)	ΔS(WY PRE-50) ΔS(MT PRE-50)	
0	+ Q(accum WY) + 2500	+	0	+	0 = 2500
0	+ Q(accum MT) + 2000	+	0	+	0 = 2000

$$Q(\text{accum}) = 2500 + 2000 = 4500$$

$$Q(\text{alloc WY}) = 4500 \times (.60) = 2700$$

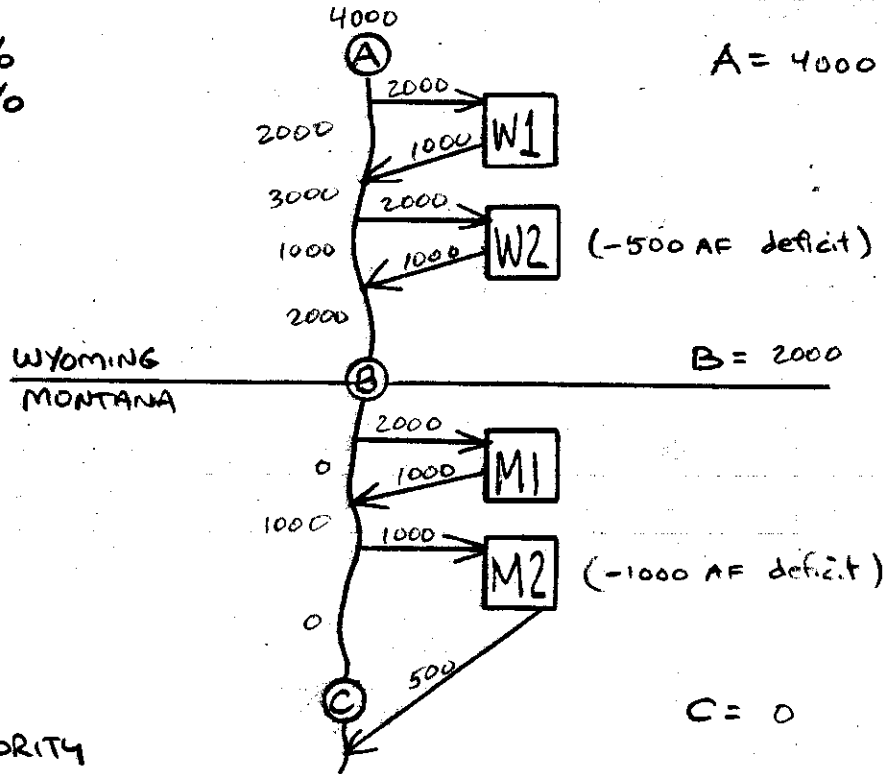
$$Q(\text{alloc MT}) = 4500 \times (.40) = 1800$$

note: There is sufficient water in both states so that no regulation is required and the 750 AF at "C" is moved to an "unused and unavailable" account.

EXHIBIT 2

YELLOWSTONE COMPACT ALLOCATION FOR THE MONTH OF JUNE

MONTANA = 40%
WYOMING = 60%



* = POST-KSD PRIORITY

STREAMFLOW FORECAST = 4000 AF

W1 = 2000 AF
* W2 = 2000 AF
M1 = 2000 AF
* M2 = 1000 AF

SUM FROM PREVIOUS MONTHS	TERM	ED(WY) ED(MT)	ΔS(WY POST-50) ΔS(MT POST-50)	ΔS(WY PRE-50) ΔS(MT PRE-50)	
2500	+ Q(accum WY)	+ 2000	+ 0	+ 0	= 4500
2000	+ Q(accum MT)	+ 1000	+ 0	+ 0	= 3000

$$Q(\text{accum}) = 4500 + 3000 = 7500$$

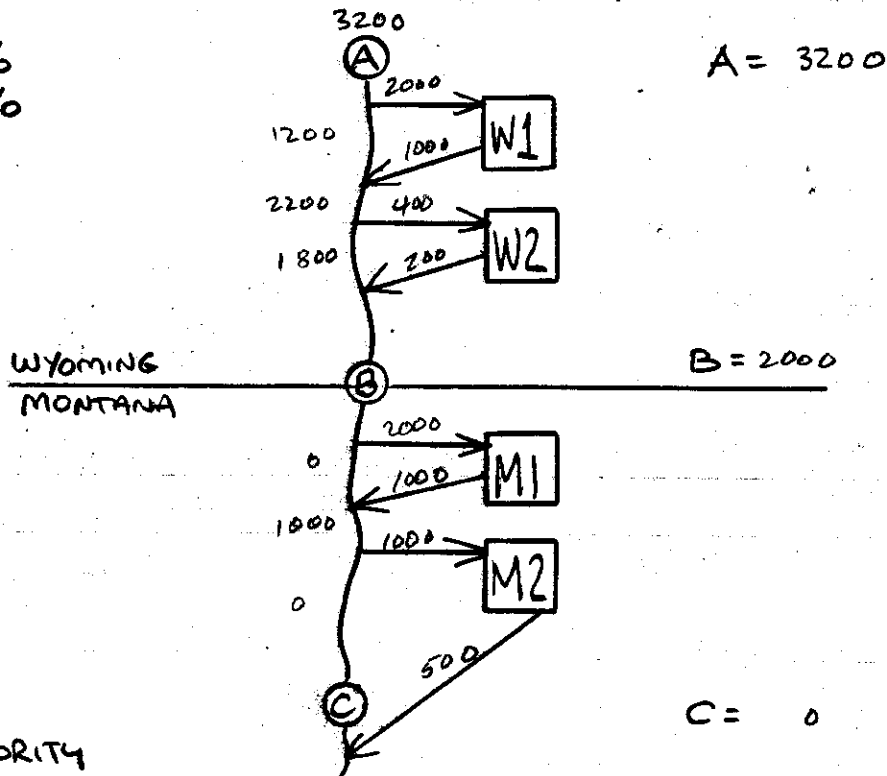
$$Q(\text{alloc WY}) = 7500 \times (.60) = 4500$$

$$Q(\text{alloc MT}) = 7500 \times (.40) = 3000$$

EXHIBIT 3

YELLOWSTONE COMPACT ALLOCATION FOR THE MONTH OF JULY

MONTANA = 40%
WYOMING = 60%



* = POST-1950 PRIORITY

STREAMFLOW FORECAST = 3200 AF

W1 = 2000 AF

* W2 = 400 AF

M1 = 2000 AF

* M2 = 1000 AF

SUM FROM PREVIOUS MONTHS	TERM	ED(WY) ED(MT)	ΔS(WY POST-50) ΔS(MT POST-50)	ΔS(WY PRE-50) ΔS(MT PRE-50)	
4500	+ Q(accum WY) +	400	0	0	= 4900
3000	+ Q(accum MT) +	1000	0	0	= 4000

$$Q(\text{accum}) = 4900 + 4000 = 8900 \text{ AF}$$

$$Q(\text{alloc WY}) = 8900 \times (.60) = 5340$$

$$Q(\text{alloc MT}) = 8900 \times (.40) = 3560$$

note: Even though $Q(\text{accum MT}) > Q(\text{alloc MT})$ and $Q(\text{accum WY}) < Q(\text{alloc WY})$, post-1950 appropriators in Wyoming must be regulated to allow 2000 AF to cross the state line to satisfy Montana's pre-1950 uses.

APPENDIX H - RESERVOIR EXAMPLE

It is suggested that the constraints found in this appendix be included in the Compact accounting model for cases where there is significant reservoir storage. These constraints are necessary because a strict interpretation of Article V would result in the division of stored water on a percentage basis that should not necessarily be divided. For example, if Wyoming stores their 60% share, and Montana's 40% share flow past the point of measurement, Article V still attempts to divide Wyoming storage on a 60/40 basis. Therefore, the purpose of the proposed constraints are:

1. To allow each state to store and use their share of Compact water.
2. To protect Montana if Wyoming oversizes their storage projects and stores more than their share of Compact water.
3. To provide a mechanism to equitably handle the problem of instream uses of water for the protection of aquatic habitats in both states.

Constraints

Define a "storage limit" for each state which is based on Article V:

$$SL_{WY} = (.60) \times [\Delta S(WY_{post50}) + \Delta S(MT_{post50}) + \sum_{day=1}^n Q(\text{compact gage}) - (\text{instream flows})]$$

$$SL_{MT} = (.40) \times [\Delta S(WY_{post50}) + \Delta S(MT_{post50}) + \sum_{day=1}^n Q(\text{compact gage}) - (\text{instream flows})]$$

Where, SL_{WY} and SL_{MT} are Wyoming's and Montana's storage limits for excess spring flow. The storage limits are to be quantified only once per year, and generally at the end of the reservoir(s) filling cycle.

For purposes of compact accounting and model building, it is suggested the storage limits be used as follows:

1. If $Q(\text{accumWY}) > Q(\text{allocWY})$;
and, $Q(\text{accumMT}) < Q(\text{allocMT})$;
and, $\Delta S(WY_{post50}) > SL_{WY}$
and, Montana appropriators need water;

THEN

regulate post-1950 uses in Wyoming (or drawdown the excess storage) until either:

- a. Montana appropriators are satisfied
 - or b. $\Delta S(WY_{post50}) = SL_{WY}$
- whichever comes first.

2. In the Compact accounting model, the change in storage which gets accumulated in the term $Q(\text{accum}WY)$ is equal to the quantity $[\Delta S(WY_{post50}) - SL_{WY}]$ and is added in only when $\Delta S(WY_{post50}) > SL_{WY}$.

These same constraints hold true for calculations with Montana's storage limits.